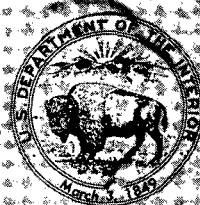


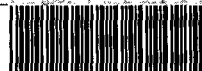
U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 84-4255



**AQUIFER TESTS AT THE
JACKPILE-PAGUATE URANIUM MINE,
PUEBLO OF LAGUNA, WEST-CENTRAL NEW MEXICO**

Albuquerque, New Mexico

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UNITED STATES DEPARTMENT OF THE INTERIOR

WILLIAM P. CLARK, Secretary

GEOLOGICAL SURVEY

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CONTENTS

	Page
Abstract	1
Introduction	1
Purpose and scope	2
Background	2
Previous investigations	2
Hydrologic units	4
Acknowledgments	4
Aquifer tests	6
Well M2	6
Well M3	11
Well M4C	14
Well M21	18
Well M25	21
Summary	23
References	25

ILLUSTRATIONS

Figure 1. Map showing location of the Jackpile-Paguate Mine and aquifer-test sites	3
2. Generalized geologic column showing major hydrologic units in the study area	5
3. Diagram showing well-completion details and geologic units penetrated by wells M2 and M2ob	7
4. Graph showing pumping rates during aquifer tests at wells M2, M3, M4C, and M21	8
5. Graphs showing drawdown in pumped well M2 and in observation well M2ob	10
6. Diagram showing well-completion details and geologic units penetrated by wells M3ob, M3, and M25	12
7. Graphs showing drawdown in pumped well M3 and in observation well M3ob	13

ILLUSTRATIONS - Concluded

	Page
Figure 8. Diagram showing well-completion details and geologic units penetrated by wells M4B, M4C, M4A, and M4	15
9. Graph showing drawdown in pumped well M4C and in observation wells M4, M4A, and M4B	17
10. Diagram showing well-completion details and geologic units penetrated by wells M21 and M21ob	19
11. Graph showing drawdown in pumped well M21 and in observation well M21ob	20
12. Graph showing result of slug test for well M25	22

CONVERSION FACTORS

In this report, values for measurements are given in inch-pound units only. The following table contains factors for converting to metric units.

<u>Multiply inch-pound units</u>	<u>By</u>	<u>To obtain metric units</u>
acre	4,047	square meter
foot	0.3048	meter
gallon per minute	0.06309	liter per second
mile	1.609	kilometer
inch	25.40	millimeter
foot per day	0.3048	meter per day
foot squared per day	0.0929	meter squared per day

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ABSTRACT

The transmissivity of the Jackpile sandstone bed in the Brushy Basin Shale Member of the Morrison Formation was determined to be 24 feet squared per day at well M2 and 47 feet squared per day at well M3 from constant-discharge aquifer tests conducted at the Jackpile-Paguate Uranium Mine. The storage coefficient of the Jackpile sandstone bed was estimated to be 0.00018 at well M2 and 0.00029 at well M3 from the same tests. An aquifer test conducted at well M21 indicated the transmissivity of the Jackpile sandstone bed was 2.0 feet squared per day and the storage coefficient was 0.00002.

The transmissivity of an unnamed sandstone bed in the Brushy Basin Shale Member of the Morrison Formation was estimated from "slug-test" results to be about 20 feet squared per day. Water levels in this sandstone probably did not change due to pumping from the overlying Jackpile sandstone bed for 88 hours at an average discharge of 15.3 gallons per minute.

A constant-discharge aquifer test at well M4C indicated that the transmissivity of the alluvium at this location was about 430 feet squared per day. Water levels in the underlying Jackpile sandstone bed began declining within 15 minutes after withdrawals of ground water from the alluvial aquifer began.

INTRODUCTION

An evaluation of the environmental impacts of alternative reclamation plans for the Jackpile-Paguate Uranium Mine was initiated by the Conservation Division of the U.S. Geological Survey and is being completed by the U.S. Bureau of Land Management. As part of this evaluation, the Water Resources Division of the U.S. Geological Survey was requested to study the hydrologic system in the vicinity of the mine. To better quantify the hydraulic properties of rocks in the mine area, five aquifer tests were conducted and are described in detail in this report.

Purpose and Scope

This report describes the methods used to evaluate the aquifer tests and lists the values of hydrologic properties determined from the tests. The scope of the report is limited to a discussion of methods and results from each aquifer test.

Sites for aquifer testing were selected from about 30 test wells drilled to monitor water levels in the mine area. The wells were selected and tested to determine the hydraulic properties of the Jackpile sandstone bed of the Morrison Formation, the alluvium near the junction of the Rio Moquino and Rio Pagate, and an unnamed sandstone unit in the Brushy Basin Shale Member of the Morrison Formation. The information on hydraulic properties obtained from the tests could be used in numerical-model predictions of ground-water flow and solute movement in the vicinity of the mine.

Background

The Jackpile-Pagate Uranium Mine is located on the Pueblo of Laguna about 30 miles east of Grants, New Mexico (fig. 1). It is one of the largest uranium mines in the world (Melancon, 1963, p. 4). Mining began in 1953 and continued through 1982, when operations ceased due to a decreased demand for uranium ore. Both open-pit and underground mining methods were used to remove the uranium-bearing Jackpile sandstone bed of the Morrison Formation. A total of 2,656 acres were affected by mining of which 485 acres have been reclaimed (Harold Zehner, U.S. Geological Survey, written commun., 1982). Reclamation is planned for all the affected area by backfilling open pits, modifying the shapes of waste-rock piles, and planting new vegetation.

Previous Investigations

Dinwiddie (1963) described the principal aquifers and well yields in the vicinity of the mine. An investigation of ground-water occurrence on parts of the Acoma and Laguna Indian lands was made by Dinwiddie and Motts (1964). A more complete study of the water resources on the entire Pueblo of Laguna was conducted by Risser and Lyford (1984). Their report describes the general availability of surface and ground water in the vicinity of the mine. Reports by Lyford (1979) and Lyford and others (1980) provide general descriptions of ground-water conditions in northwestern New Mexico.

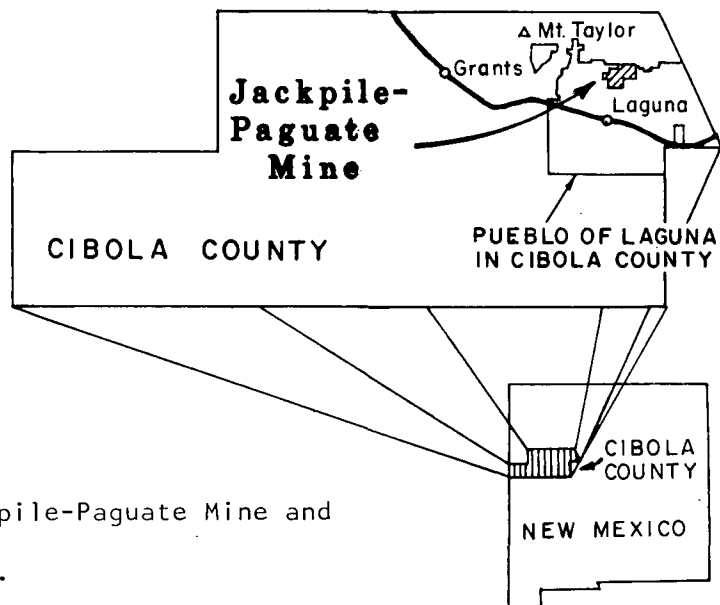
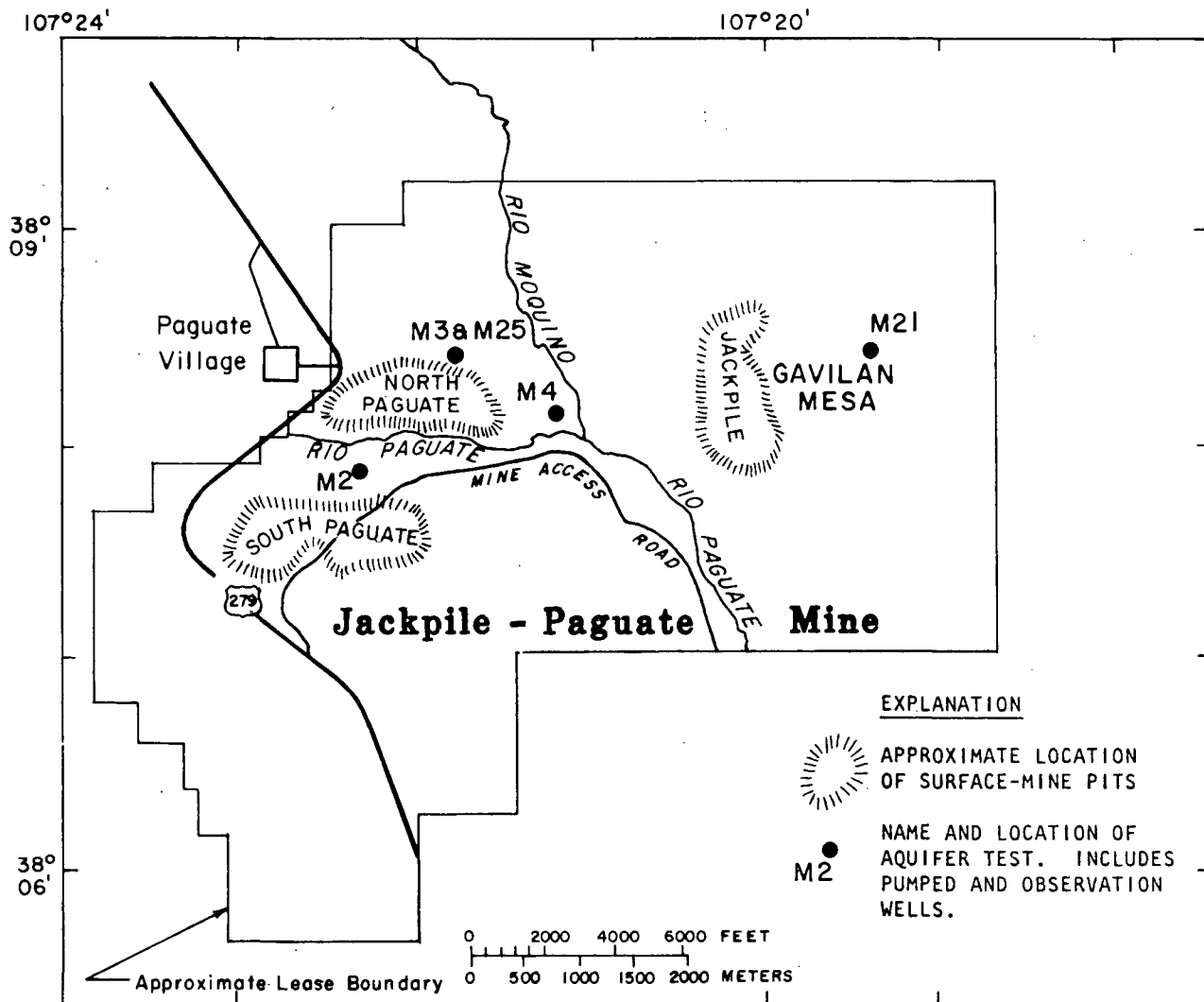


Figure 1.--Location of the Jackpile-Paguete Mine and aquifer-test sites.

Hydrologic Units

Hydrologic units exposed in the vicinity of the Jackpile-Paguate Mine include strata from Late Jurassic to Quaternary age (fig. 2). The following summary of the physical properties of these units is mainly from Moench and Schlee (1967).

The uppermost member of the Morrison Formation (of Late Jurassic age), the Brushy Basin Shale Member, generally is a grayish-green, silty to sandy mudstone. In a few places, the mudstone is almost all clay. The total thickness of this member ranges from about 300 to 500 feet. Locally, sandstone beds as thick as 200 feet are found in the Brushy Basin Shale Member. One such sandstone bed is the Jackpile sandstone bed, the major uranium-bearing unit of the Jackpile-Paguate Mine. This sandstone is in the uppermost part of the Brushy Basin Shale Member and is fine to medium grained and poorly to moderately well sorted. It is composed of detrital quartz with calcite cement in the basal part, becoming increasingly clay-cemented upward. In the wells tested, the thickness of the Jackpile sandstone bed ranges from 39 feet at well M4 to 162 feet at well M2.

The Dakota Sandstone, of Cretaceous age, unconformably overlies the Jurassic rocks. In the mine area, the Oak Canyon Member of the Dakota Sandstone unconformably overlies the Jackpile sandstone bed. The lower part of the Oak Canyon Member is composed of orange or brown, fine-grained silty sandstone, whereas the upper part is predominantly siltstone and shale. Where present at the wells tested, the thickness of the Oak Canyon Member ranges from 39 feet at well M2 to 180 feet at well M3.

Alluvium of Quaternary age is present along the Rio Moquino and Rio Paguate, where it was deposited in channels cut in the Mancos Shale, Oak Canyon Member of the Dakota Sandstone, and Brushy Basin Shale Member of the Morrison Formation. The alluvium consists of sand, silt, and gravel with occasional lenses of clay. Thickness of the alluvium ranges from 60 to 68 feet near the junction of the Rio Moquino and Rio Paguate at wells M4, M4A, M4B, and M4C.

Acknowledgments

The authors wish to thank personnel of Anaconda Minerals Company for their assistance in conducting the aquifer tests. Meade Stirland, Environmental Division, was particularly helpful in providing existing hydrologic data for the mine area. James Basler of the U.S. Geological Survey provided the expertise needed to conduct the aquifer tests using pressure transducers.

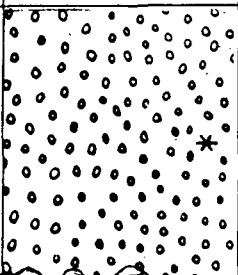
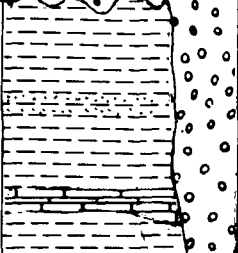
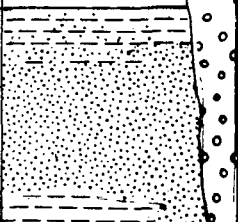
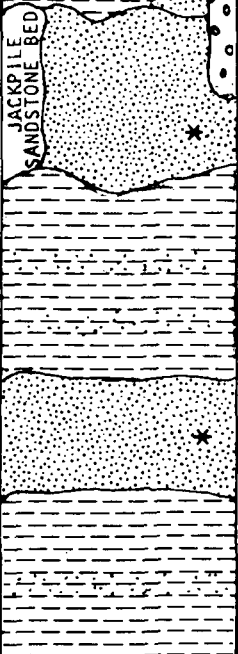
SYSTEM	FORMATION	MEMBER	LITHOLOGY (* DENOTES HYDROLOGIC UNIT TESTED)	APPROXIMATE THICKNESS	DESCRIPTION (Modified from Moench and Schlee, 1967)
QUATERNARY	ALLUVIUM	—		0-80	Sand, gravel, and silt deposited along the Rio Paguete and Rio Moquino. Discontinuous clay lenses also are present. The alluvium lies unconformably on Mancos Shale, Dakota Sandstone and the Morrison Formation in the mine area.
CRETACEOUS	MANCOS SHALE	—		0-150	Shale, dark gray to black; minor amounts of siltstone. Thin layers of bentonite and limestone also are present.
JURASSIC	DAKOTA SANDSTONE	OAK CANYON		0-180	Sandstone and siltstone; gray to tan, fine- to coarse-grained, calcareous and carboniferous. Thin shale layers are similar in lithology to the Mancos Shale.
JURASSIC	MORRISON FORMATION	BRUSHY BASIN SHALE MEMBER		300-500 FEET	Mudstone, grayish-green, mottled red in places, interbedded with layers of siltstone and sandstone. The uppermost sandstone is the Jackpile sandstone bed, which consists of 90-200 feet of kaolinitic, carbonaceous sandstone. The Jackpile sandstone bed is cemented mainly by calcite near its base and clay near the top. An unnamed sandstone bed about 115 feet below the bottom of the Jackpile sandstone bed. This sandstone is about 60 feet thick and similar in lithology to the Jackpile sandstone bed.

Figure 2.--Generalized geologic column showing major hydrologic units in the study area.

AQUIFER TESTS

The alluvium near the junction of the Rio Paguete and Rio Moquino, the Jackpile sandstone bed, and an unnamed sandstone unit in the Brushy Basin Shale Member of the Morrison Formation were tested to estimate values for transmissivity and storage coefficient. The alluvium was tested at well M4C; the Jackpile sandstone bed was tested at wells M2, M3, and M21; and the unnamed sandstone unit was tested at well M25 (fig. 1). The transmissivity and storage values of these aquifers presented in this report were estimated using only drawdown data. Recovery data were collected and analyses of these data yielded results nearly identical to the drawdown data. Therefore, a discussion of the recovery tests is not presented in this report.

Well M2

Hydraulic properties of the Jackpile sandstone bed were estimated at aquifer-test site M2, located near the South Paguete Pit (fig. 1). The pumped well, M2, and nearby observation well, M2ob, are both gravel packed and open to the entire thickness of the Jackpile sandstone bed (fig. 3). At well M2, the Jackpile sandstone bed is 162 feet thick, 93 feet of which is saturated.

A constant-discharge aquifer test (Lohman, 1972, p. 15) was performed by withdrawing water from well M2. The test began on August 19, 1981. The water-level response was measured in the pumped well and in observation well M2ob, which was located 54 feet from M2. The rate of ground-water discharge averaged 5.1 gallons per minute for about 43 hours (fig. 4). The discharged water was diverted away from the well to an arroyo. Water-level response was monitored in each well by downhole pressure transducers, which were connected to a digital recorder at the surface. The pressure transducer in well M2ob automatically compensated for changes in barometric pressure. Adjustments of the transducer readings from well M2 for fluctuations in barometric pressure were made manually using measurements taken at the well site during the test.

Before analyzing the data, an additional correction was made to the drawdown data. The prepumping water-level trend of 0.002 foot per hour was subtracted from the water-level responses in both wells M2 and M2ob.

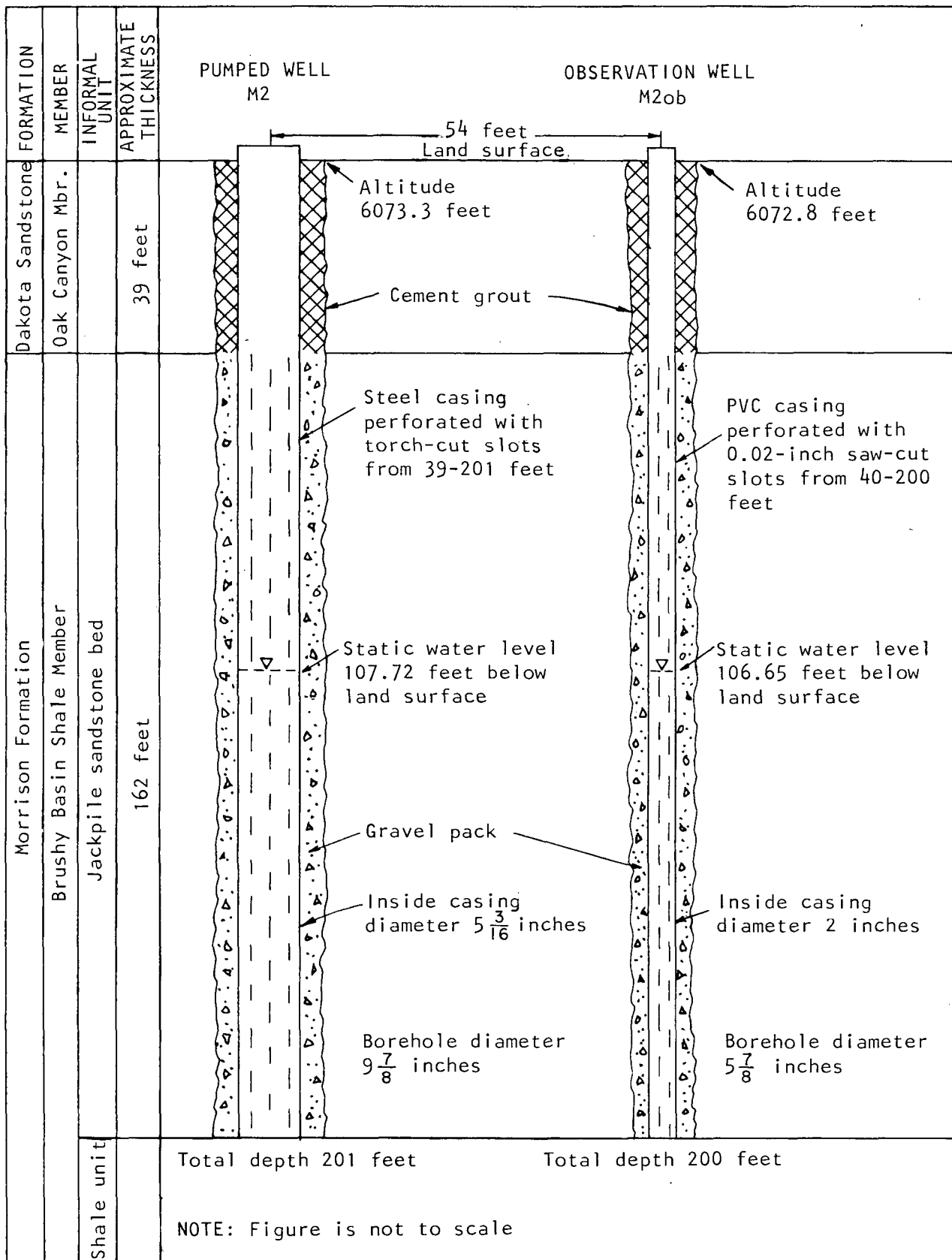


Figure 3.--Well-completion details and geologic units penetrated by wells M2 and M2ob.

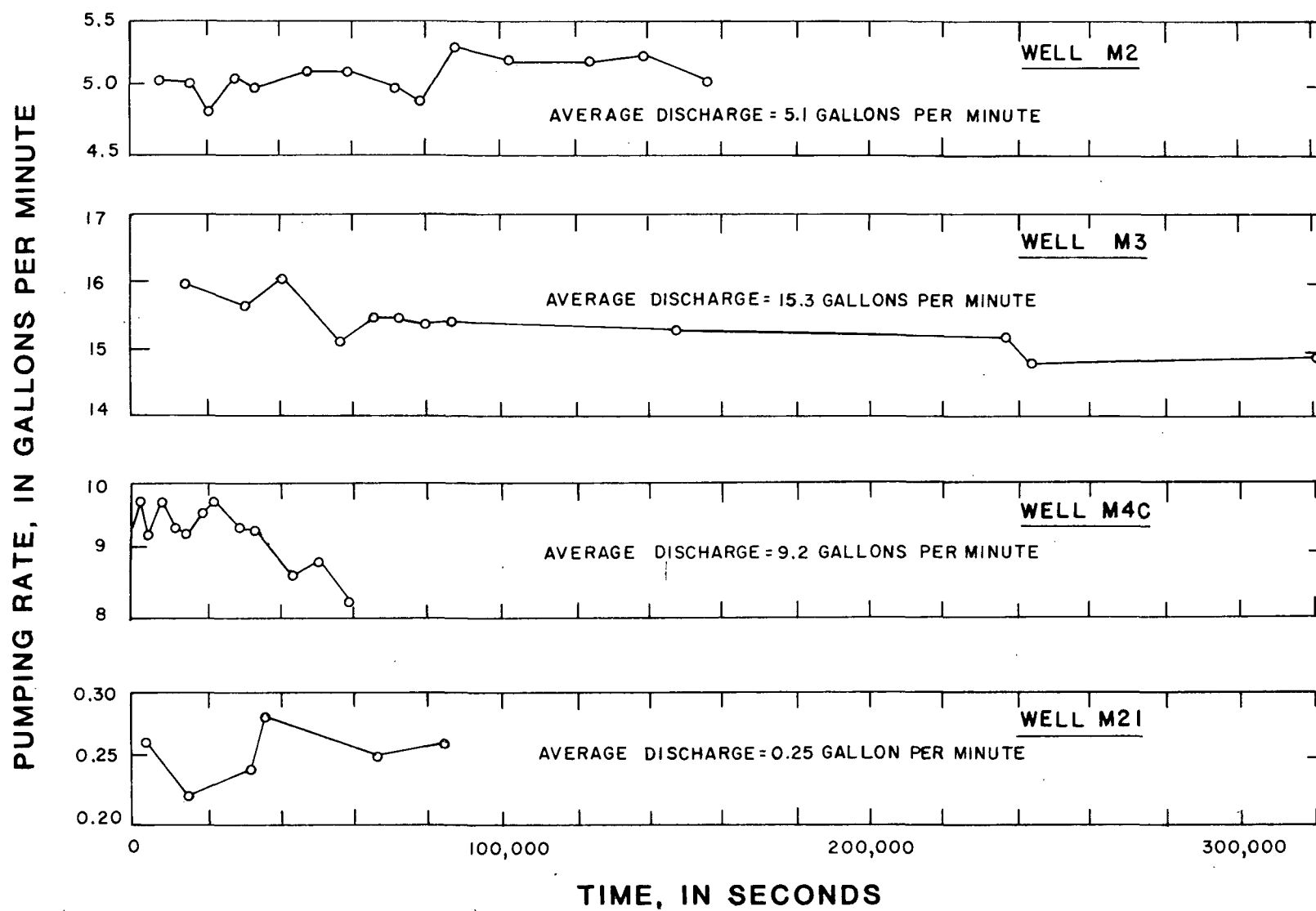


Figure 4. -- Pumping rates during aquifer tests at wells M2, M3, M4C, and M21.

Time-drawdown curves were plotted using the corrected data for wells M2 and M2ob (fig. 5). Standard curve-matching procedures (Lohman, 1972, p. 18) were used to obtain values for transmissivity and storage coefficient of the Jackpile sandstone bed at wells M2 and M2ob. A nonsteady-state, water-table type curve (Bolton, 1954) was used to match the data from each well separately. An acceptable curve fit was obtained for well M2, the pumped well, by matching time-drawdown data recorded after 150 seconds of the test had elapsed. Drawdown of water in the first 150 seconds of the test was greater than would be predicted by the type curve. Drilling fluids could have decreased the permeability of the Jackpile sandstone bed near the well, which could cause the observed deviation of time-drawdown data. From the type-curve match for drawdown of water in the pumped well, a transmissivity of 10 feet squared per day was calculated. For observation well M2ob, the time-drawdown data were matched to a nonsteady-state, water-table type curve. A transmissivity value of 24 feet squared per day was calculated for the Jackpile sandstone bed from this match.

The transmissivity of the Jackpile sandstone bed at the test site probably is better represented by the value determined from the drawdown in observation well M2ob. The drawdown measured in the observation well is less affected by small fluctuations in the pumping rate and the large vertical gradients near the pumped well. Also, the quantity of water withdrawn from storage within the observation wellbore is small. Hydraulic conductivity for the Jackpile sandstone bed near wells M2 and M2ob was estimated to be about 0.26 foot per day by dividing the transmissivity of 24 feet squared per day by the 93-foot saturated thickness at well M2.

A storage coefficient of 0.00018 was calculated from the drawdown data at well M2ob (fig. 5). Apparently, during the first part of the test, water released from storage was provided by expansion of water in the aquifer and compaction of the aquifer. For times greater than about 2,000 seconds, the measured drawdown was less than would be predicted using the Theis (1935) solution. Possibly this "extra water," unaccounted for by the Theis solution, is provided by dewatering of the unconfined aquifer. The long delay before dewatering of the aquifer begins would be expected for consolidated fine-grained sand and clay materials that compose the Jackpile sandstone bed. The specific yield could not be determined for the Jackpile sandstone bed because the duration of the test was too short. Using Bolton's theory (Prickett, 1965, p. 6), and assuming a specific yield of the aquifer of 0.05, the calculated time after which the delayed yield of water from storage would cease to affect drawdown measured in M2ob is greater than 1 year.

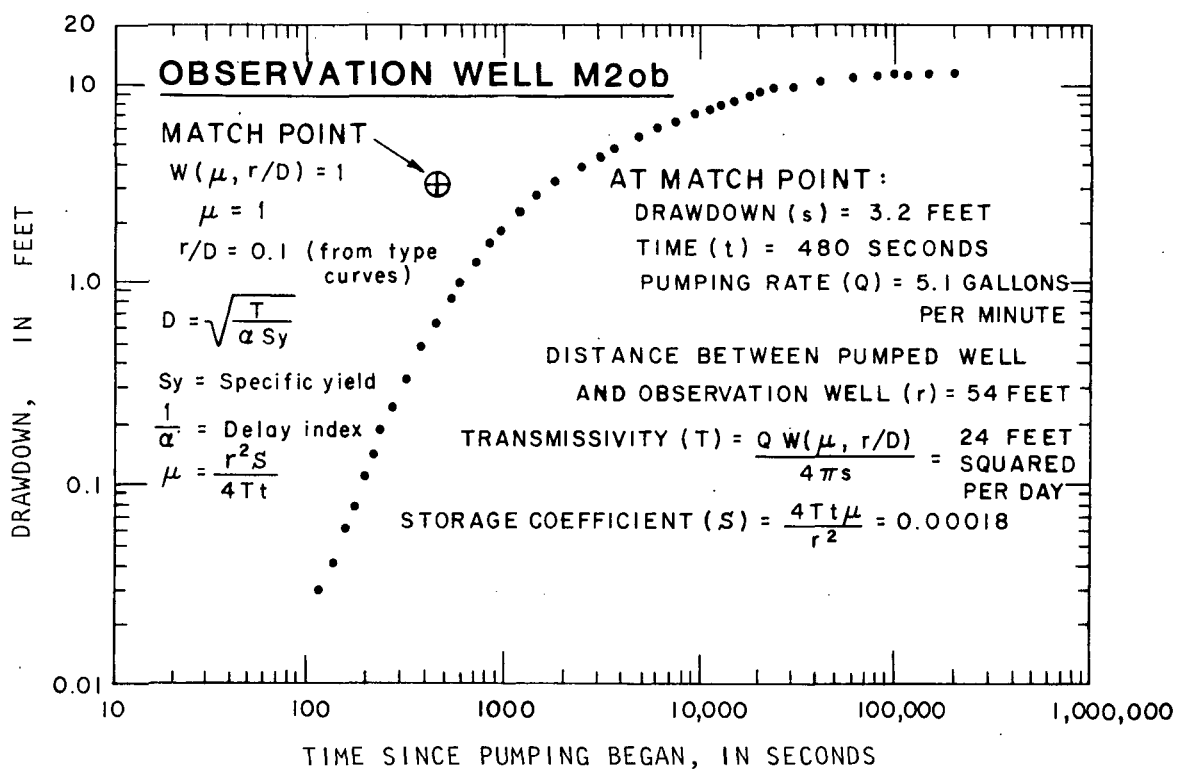
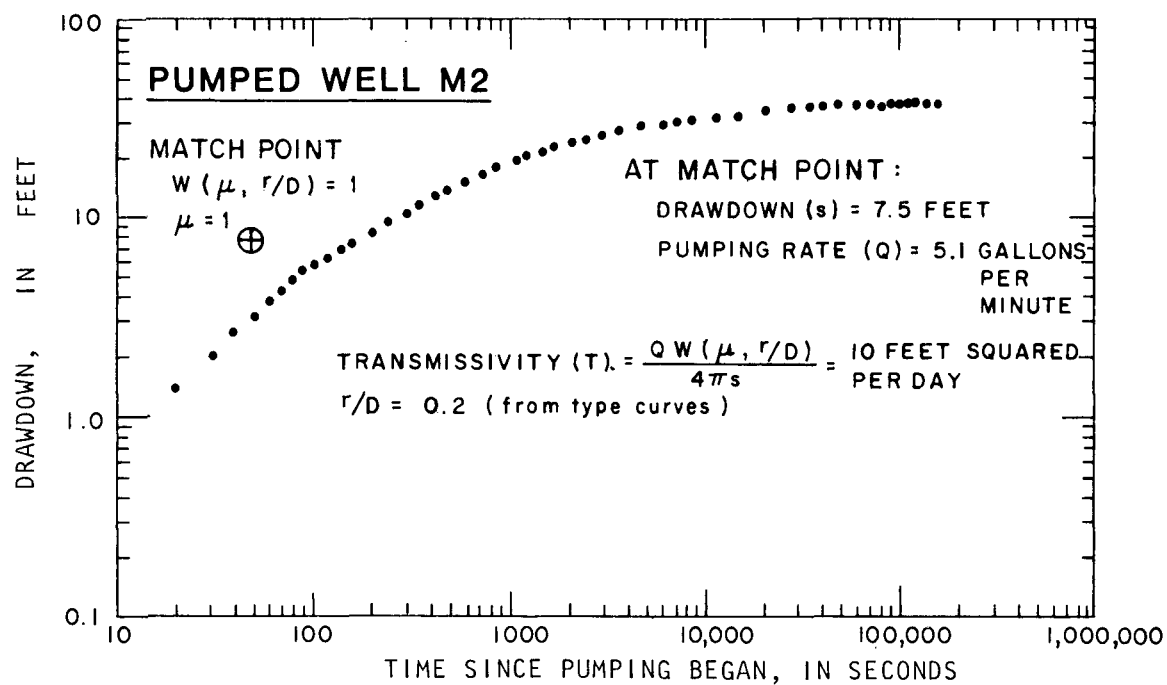


Figure 5.--Drawdown in pumped well M2 and in observation well M2ob.

Well M3

An aquifer test also was performed at well M3, which was completed in the Jackpile sandstone bed near the North Paguate Pit (fig. 1). Well M3 and observation well M3ob, located 44 feet away, are gravel packed and open to the entire thickness of the Jackpile sandstone bed (fig. 6). Well M25, which also was used as an observation well for this test, is completed in an unnamed sandstone bed within the Brushy Basin Shale Member of the Morrison Formation. The sandstone bed lies beneath the Jackpile sandstone bed and is separated from it by about 115 feet of shale.

The water level in wells M3 and M3ob was about 20 feet above the top of the Jackpile sandstone bed. Water in the Jackpile sandstone probably is confined at this location by a shale unit in the Dakota Sandstone, which directly overlies the Jackpile sandstone bed.

To determine aquifer properties at this location, well M3 was pumped at an average discharge rate of 15.3 gallons per minute for 88 hours beginning on August 24, 1981 (fig. 4). The discharge water was diverted away from the well. Water levels were monitored in wells M3 and M3ob by downhole pressure transducers. Changes in barometric pressure were compensated for automatically by the transducer in well M3ob. Measurement of barometric pressure was made at the well site to manually correct readings from the pressure transducer used in well M3. Periodic steel-tape measurements of the water levels were also made to correct pressure-transducer readings for the effects of instrument drift. In addition, a correction factor of 0.0025 foot per hour was subtracted from the drawdown at wells M3 and M3ob to compensate for the declining prepumping water-level trend. Also, drawdowns were adjusted as much as 0.73 foot at M3ob and 7.45 feet at M3 to correct for the decreasing saturated thickness of the aquifer using the method described by Jacob (1963, p. 246). The water level in well M25 was monitored with a steel tape and m-scope electronic probe.

The corrected drawdown as a function of time for wells M3 and M3ob is shown in figure 7. An unexplained "blip" in the drawdown curves at wells M3 and M3ob occurred at about 400 seconds. The "blip" occurred at about the same time that the water level in the pumped well fell below the top of the Jackpile sandstone bed. The anomaly resembles the change from artesian to water-table conditions observed in other tests. However, the anomaly occurred in the pumped well and observation well at nearly the same time, which would not be the case for a change from confined to unconfined conditions. A possible explanation for the "blip" is that an undetected fluctuation in the power supply for the data logger occurred.

Standard curve-matching procedures were used to obtain values for the transmissivity of the Jackpile sandstone bed at well M3 and M3ob (fig. 7). A nonsteady-state type curve (Theis, 1935) was used to match the data from both wells. An acceptable curve fit was obtained for well M3, the pumped well, by matching the entire set of time-drawdown data. From the type-curve match, a transmissivity of 47 feet squared per day was calculated. For observation

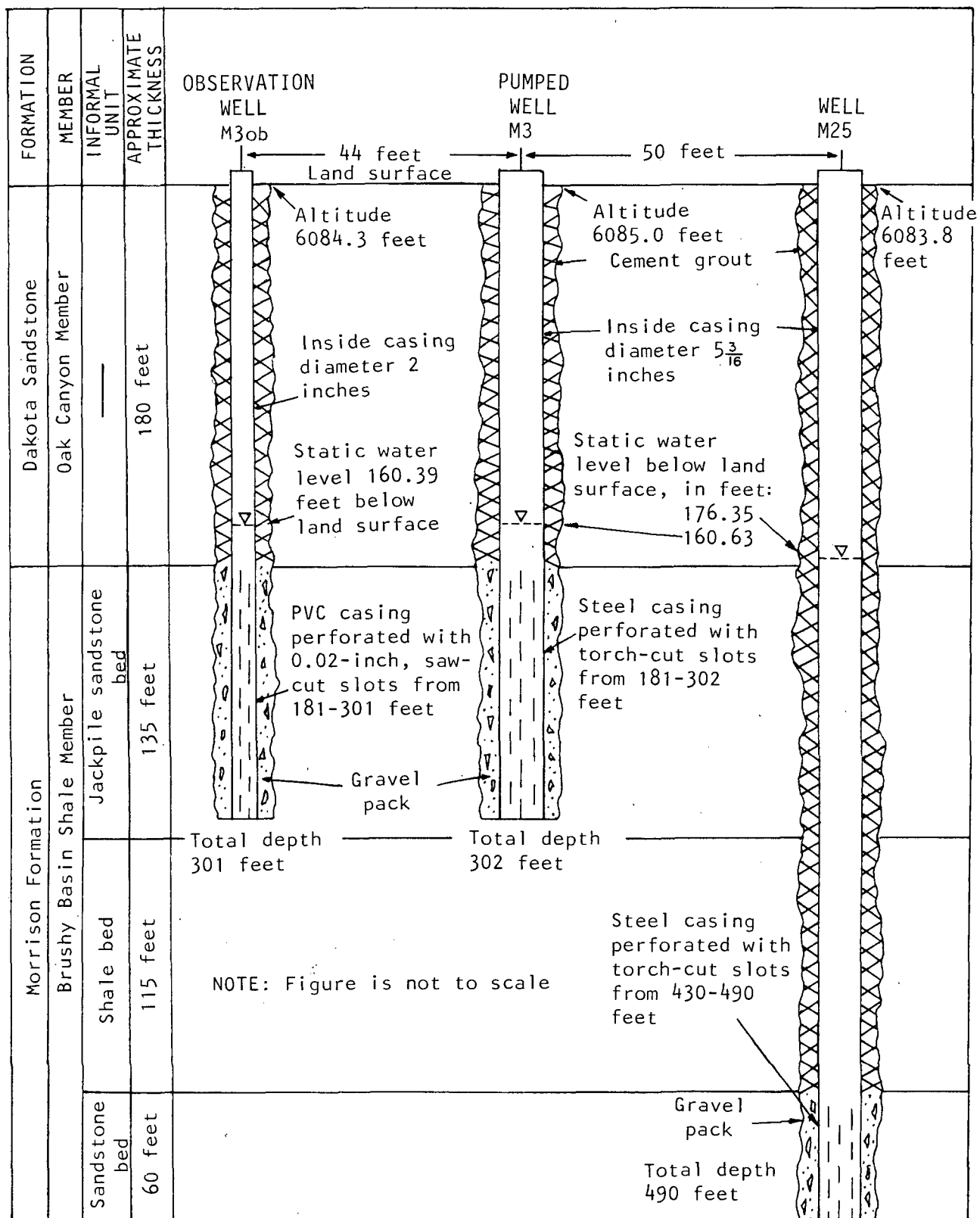


Figure 6.--Well-completion details and geologic units penetrated by wells M3ob, M3, and M25.

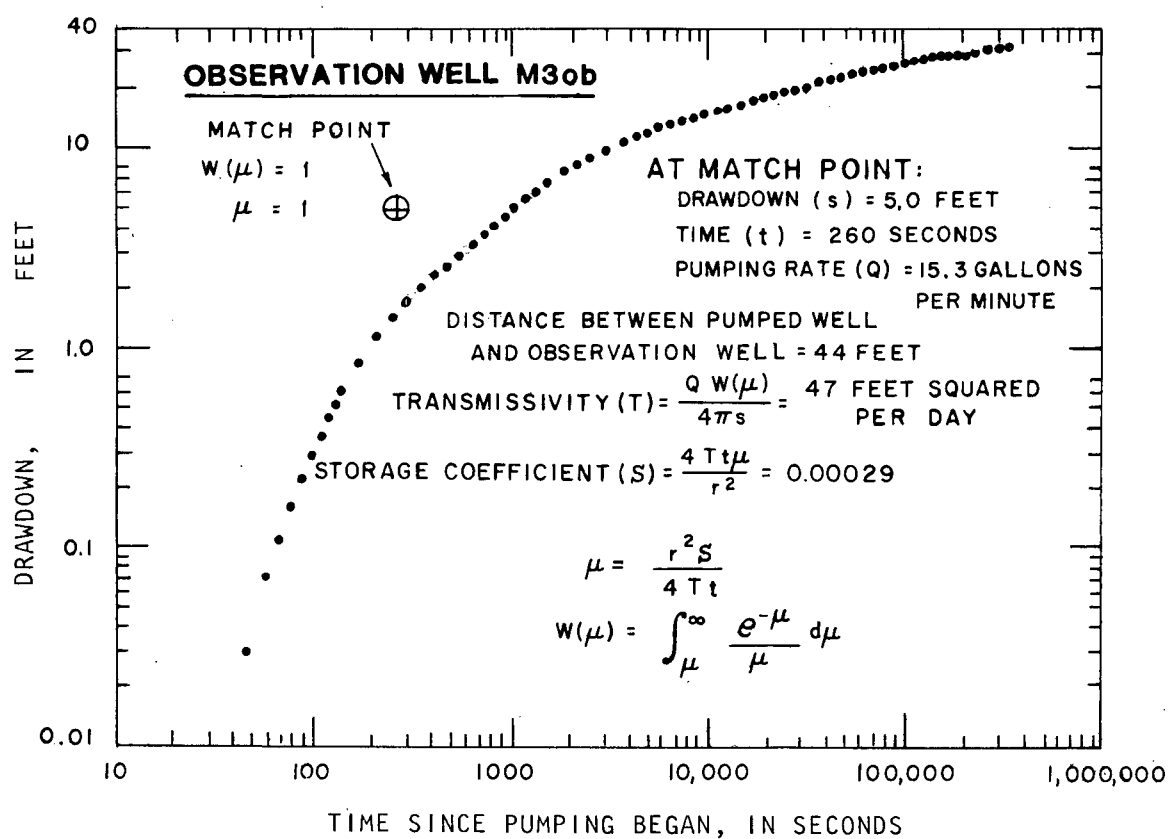
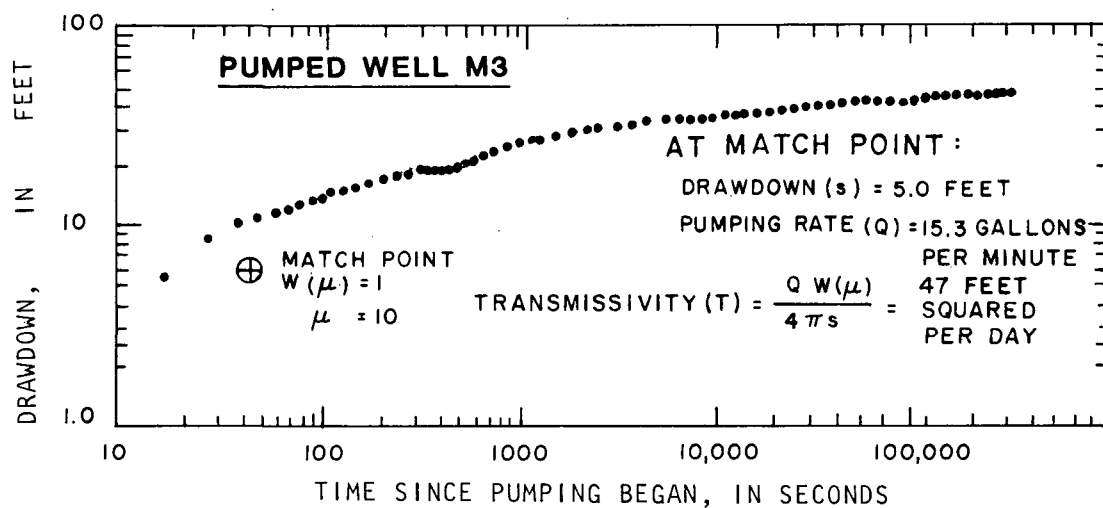


Figure 7.--Drawdown in pumped well M3 and observation well M3ob.

well M3ob, the time-drawdown data recorded after 400 seconds of the test had elapsed were matched to a nonsteady-state type curve. A transmissivity value of 47 feet squared per day also was calculated for the Jackpile sandstone bed from this match.

The hydraulic conductivity of the Jackpile sandstone bed in the vicinity of wells M3 and M3ob is about 0.39 foot per day. This value was calculated by dividing the transmissivity of 47 feet squared per day by the 120-foot saturated thickness at well M3ob. The storage coefficient of 0.00029 obtained from the M3ob data (fig. 7) represents the artesian response of the aquifer.

In observation well M25, located 50 feet from the pumped well, the water level remained about 3 feet above the top of the Jackpile sandstone bed throughout the duration of the aquifer test. The water level in M25 declined a maximum of 0.03 foot during the test. This small change could easily have been caused by fluctuations in barometric pressure, which varied 0.16 inch of mercury during the test. The test indicates that the shale that separates the Jackpile sandstone bed from the sandstone bed open to well M25 probably has a small vertical hydraulic conductivity. The small vertical hydraulic conductivity of the shale delays the effects of pumping between the two sandstone units.

Well M4C

An aquifer test was conducted at well M4C to determine aquifer characteristics in the alluvium and to test the hydraulic connection between the alluvium and the underlying Jackpile sandstone. The pumped well (M4C) and its accompanying observation wells (M4A, M4B, M4) are located near the junction of the Rio Paguete and Rio Moquino (fig. 1). Wells M4 and M4A were drilled through the entire thickness of Jackpile sandstone and are completed in about the bottom 20 feet of the Jackpile sandstone with casing perforated with torch-cut slots (fig. 8).

The hydraulic heads measured in the alluvium are about 1 to 2 feet higher than the hydraulic head of water in the Jackpile sandstone bed (fig. 8). Therefore, ground water moves from the alluvium to the Jackpile sandstone bed. No obvious confining unit separates the alluvium from the Jackpile sandstone bed at this location.

A constant-discharge aquifer test (Lohman, 1972) was begun on August 21, 1981. Well M4C was pumped at an average rate of 9.5 gallons per minute, but after 5 hours of pumping the test was stopped due to generator failure. After allowing water levels in the wells to recover for 13 hours, the test was restarted. At that time the water level in observation well M4B had recovered to within 0.02 foot of the prepumping water level, and the water level in the

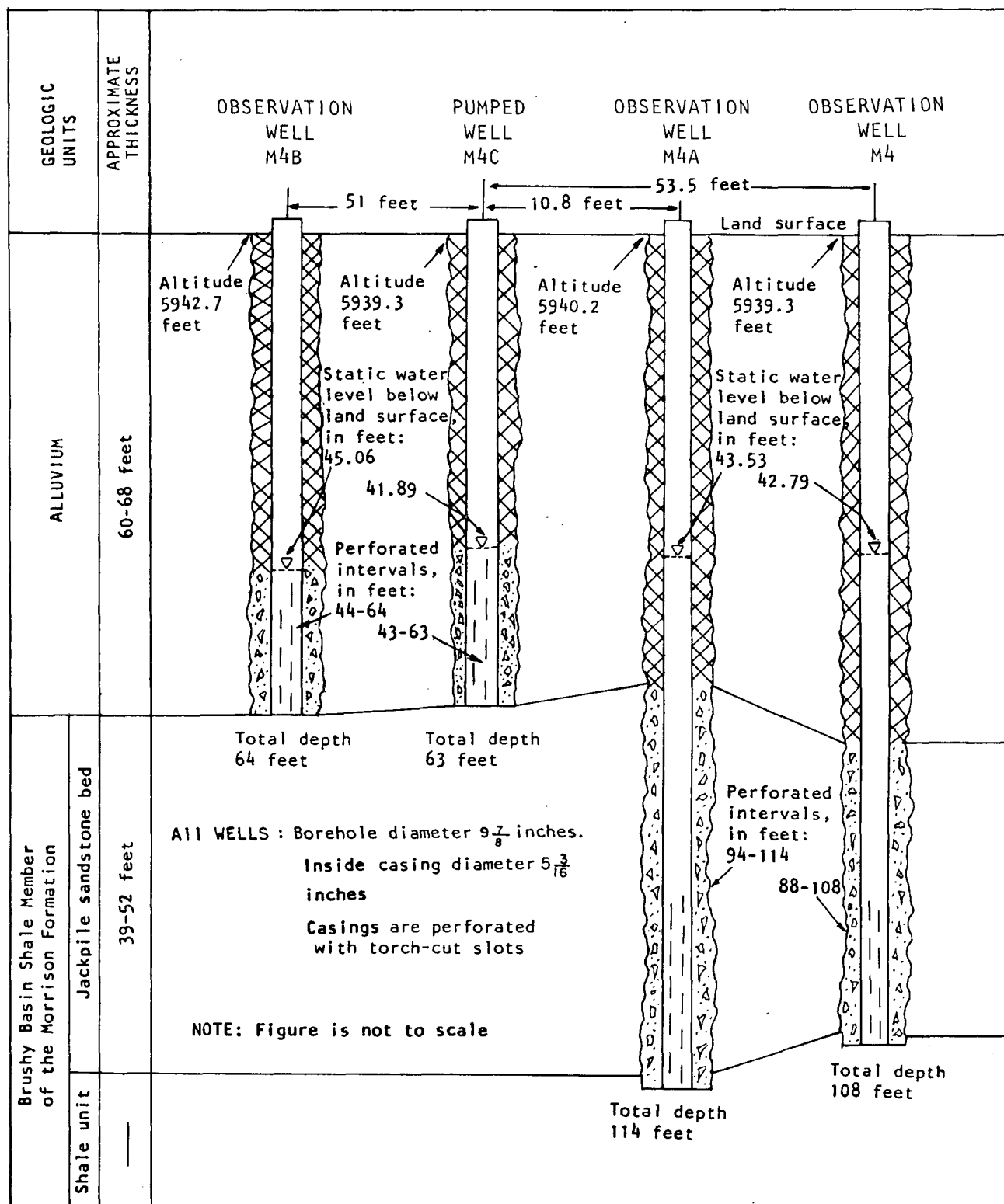


Figure 8.--Well-completion details and geologic units penetrated by wells M4B, M4C, M4A, and M4.

pumped well M4C was 0.10 foot lower than the prepumping level. Well M4C was then pumped for 17.5 hours at an average rate of 9.2 gallons per minute (fig. 4). Water-level declines in the alluvium and Jackpile sandstone bed were monitored at wells M4, M4A, M4B, and M4C with pressure transducers connected to a digital recorder at the surface. Changes in barometric pressure were automatically compensated for by the transducers in wells M4B and M4A. Data from the transducers in wells M4C and M4 were adjusted manually for changes in barometric pressure. Water-level measurements were made at regular intervals using a steel tape to ensure that the transducer readings were accurate. Drawdown data also were corrected as much as 0.12 foot at well M4B and 0.08 foot at well M4C by a method described by Jacob (1963) to compensate for the decreasing saturated thickness of the aquifer. Corrections to the drawdown data were needed to compensate for the prepumping water-level trend only at the pumped well M4C.

The corrected time-drawdown data were plotted for observation well M4B, located 51 feet from the pumping well, to determine the hydraulic properties of the alluvium at this location (fig. 9). The drawdown recorded in pumped well M4C was too irregular to analyze, probably because of surges in the pumping rate. The data from well M4B were analyzed using standard curve-matching techniques and type curves for nonsteady radial flow (Theis, 1935). The drawdown data collected before 1,500 seconds indicated a transmissivity for the alluvium of about 430 feet squared per day. After 1,500 seconds, less drawdown was measured than would be predicted by the Theis method. The deviation could be caused by delayed yield of water by gravity drainage, by upward leakage of water from the underlying Jackpile sandstone bed, by seepage through the streambed of the nearby Rio Moquino and Rio Paguate, or by the decreased pumping rate. Dividing the apparent transmissivity of 430 feet squared per day by the approximate saturated thickness of the alluvium of 19 feet resulted in a hydraulic conductivity of about 23 feet per day for the alluvium near the M4 wells.

An apparent specific yield of 0.0021 was calculated for the alluvium from the drawdown data for well M4B (fig. 9). Evidently, water mainly was released from artesian storage during the first 1,500 seconds of the test. This value is unreasonably low for a specific yield of an aquifer composed of unconsolidated sands, gravels, and clays. The drawdown data at M4B after 1,500 seconds may be responding to the delayed dewatering of the aquifer. The long-term specific yield of materials similar in composition to the alluvium at this location has been reported to be between 10 and 20 percent (Johnson, 1967).

Water levels in observation wells M4 and M4A, completed in the Jackpile sandstone bed, declined a total of 0.25 and 0.24 foot, respectively, due to pumping from the alluvium (fig. 9). These declines indicate that ground water flows between these aquifers at this location.

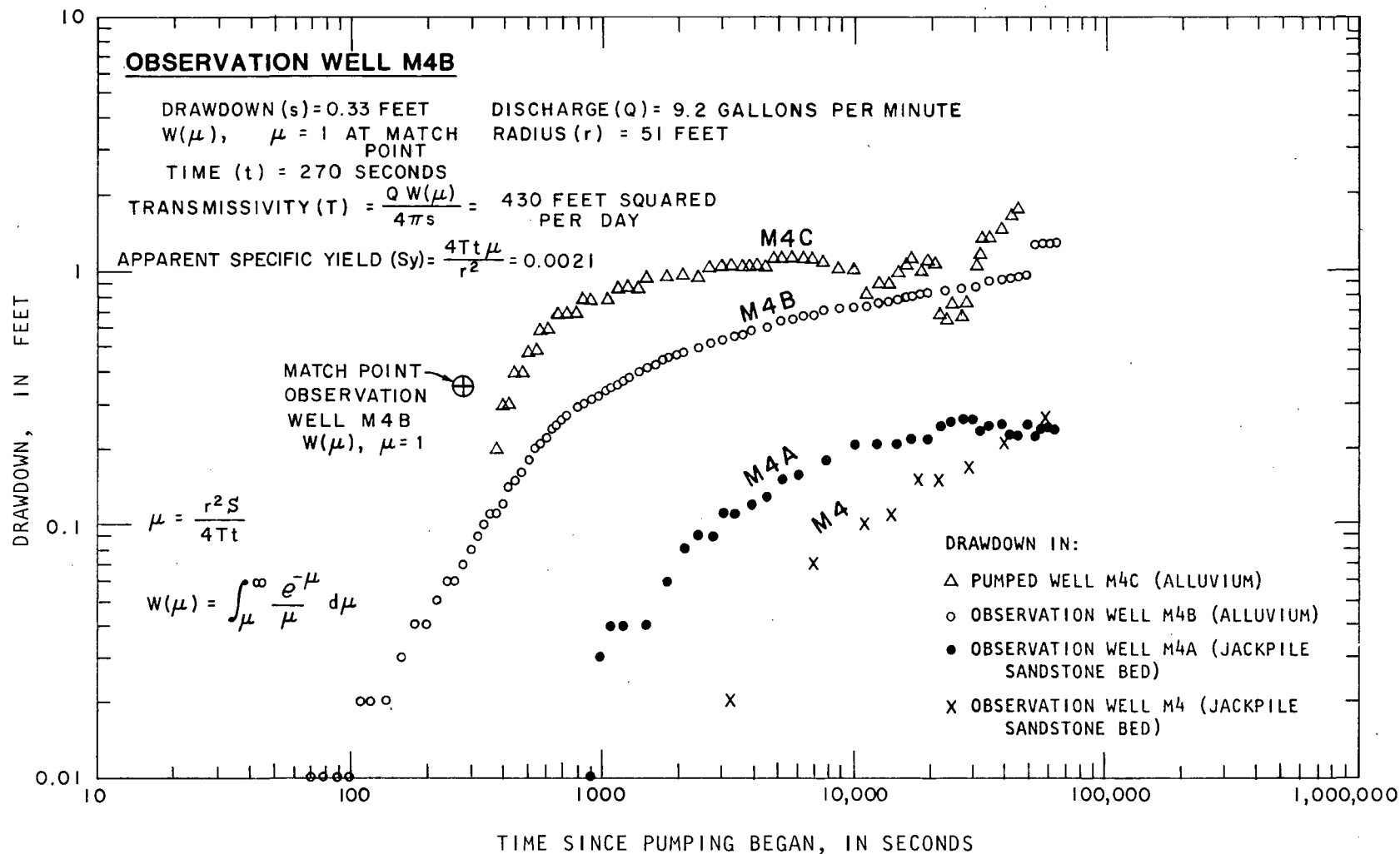


Figure 9.--Drawdown in pumped well M4C and in observation wells M4, M4A, and M4B.

Well M21

The hydraulic properties of the Jackpile sandstone bed were tested at wells M21 and M21ob, located northeast of the Jackpile Pit near Gavilan Mesa (fig. 1). Both the pumped well (M21) and the observation well (M21ob) were gravel packed and open to the entire thickness of the Jackpile sandstone bed (fig. 10). The Jackpile sandstone bed is 140 feet thick at both wells, although the saturated thickness is about 81 feet at M21ob and 83 feet at M21.

An aquifer test was conducted by pumping well M21 at an average discharge of about 0.25 gallon per minute for about 24 hours (fig. 4). Drawdown was monitored in the pumped well and in the observation well, which is located 57 feet away. The water-level declines were measured using downhole pressure transducers. The pressure transducer in well M21ob automatically compensated for changes in barometric pressure. Adjustments for changes in barometric pressure at well M21 were made manually using measurements taken at the well site during the test. The drawdowns were corrected for the effect of decreasing saturated thickness by a method described by Jacob (1963) by as much as 9.14 feet in well M21 and 0.29 foot in well M21ob. Corrections for prepumping water-level fluctuations were not needed.

Corrected values of drawdown were plotted against time for wells M21 and M21ob (fig. 11). Curve-matching procedures were used to attempt to fit the data from each well. In M21, the data collected during the first 100 seconds of the test appear to have been affected by wellbore storage (fig. 11). After 100 seconds, the time-drawdown curve displays an abrupt change in slope. The slope changes from the steep, straight-line segment dominated by wellbore storage, to a flatter section of the curve between 100 and 10,000 seconds, which has a shape similar to theoretical curves developed for an aquifer where water released by dewatering is delayed. The data collected after 10,000 seconds of pumping are probably free of borehole and delayed-drainage effects but may be affected by boundaries.

The time-drawdown data at observation well M21ob were analyzed according to a method developed by Papadopoulos and Cooper (1967) and discussed in Reed (1980, p. 37). The assumptions for this method are the same as for the Theis solution except that the volume of water withdrawn from storage in the pumped well is considered. Transmissivity of the Jackpile sandstone bed is about 2.0 feet squared per day according to the type-curve match in figure 11. Storage coefficient is estimated to be about 0.00002. Apparently, the aquifer properties of the Jackpile sandstone bed are about one-tenth as large at this location as at other test sites. Possibly the entire saturated thickness was not contributing water to the pumped well. However, if the entire thickness were contributing, the hydraulic conductivity of the Jackpile sandstone bed at this location would be about 0.025 foot per day.

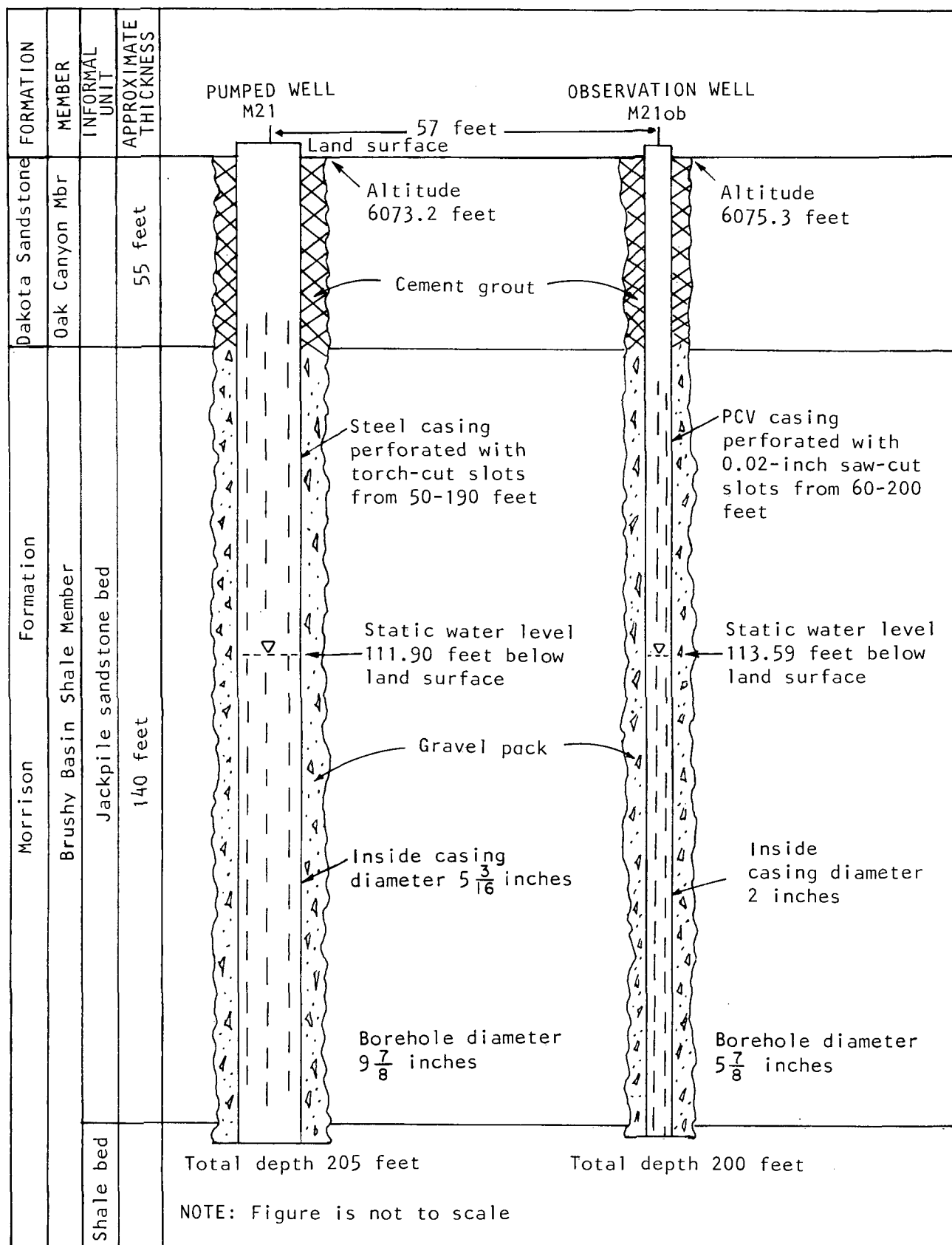


Figure 10.--Well-completion details and geologic units penetrated by wells M21 and M21ob.

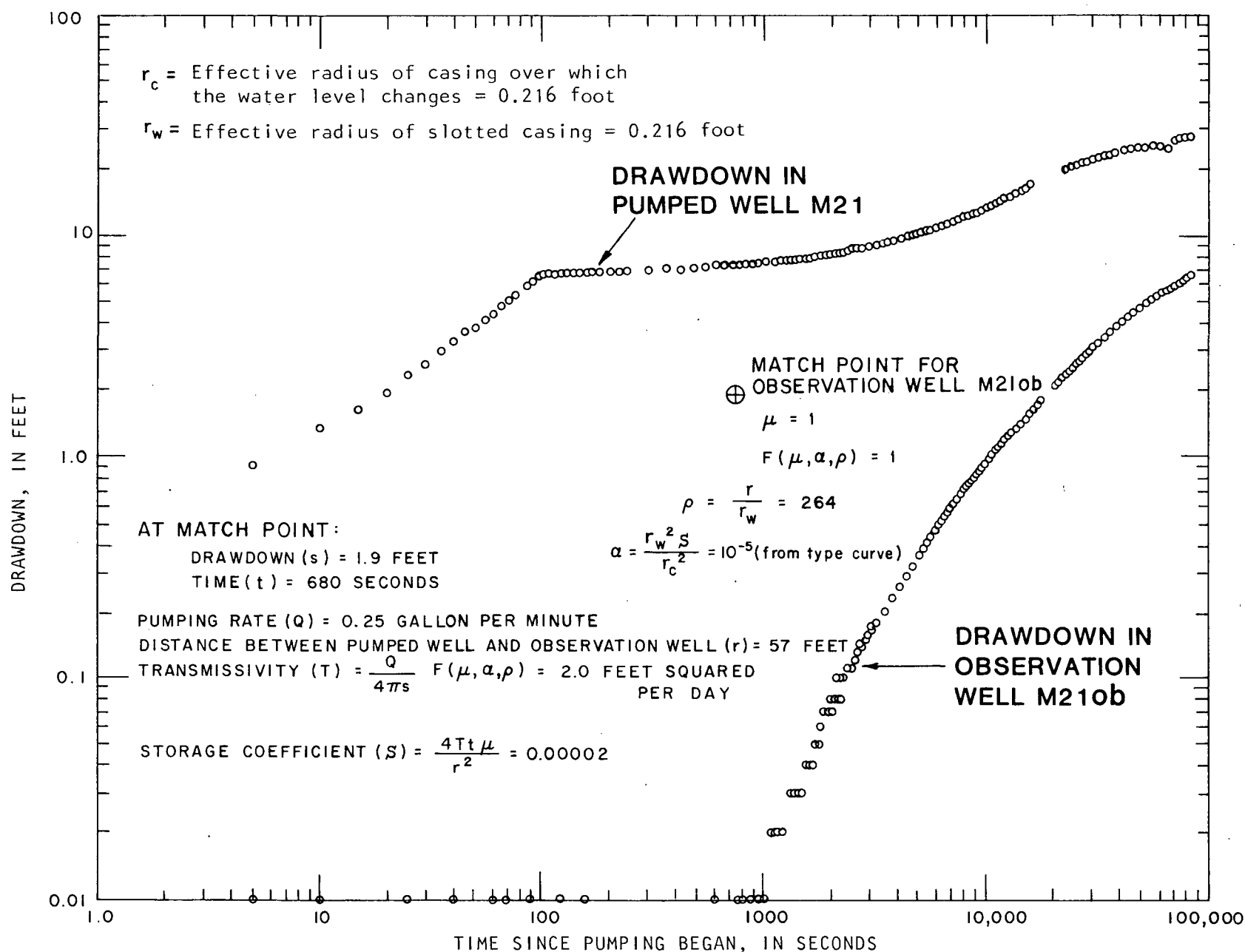


Figure 11.--Drawdown in pumped well M21 and in observation well M21ob.

Well M25

A "slug-type" aquifer test (Lohman, 1972, p. 27) was conducted at well M25, located near the North Paguate Pit (fig. 1). The purpose of the test was to determine the transmissivity at that location of an unnamed sandstone bed in the Brushy Basin Shale Member of the Morrison Formation. The well was gravel packed and open only to the 60-foot-thick sandstone bed (fig. 6). This sandstone bed is separated from the Jackpile sandstone bed by about 115 feet of shale of the Brushy Basin Shale Member. Prior to the aquifer test, the water level in well M25 was about 254 feet above the top of the sandstone bed, indicating that water in the formation was under confined conditions.

The aquifer test was conducted by rapidly lowering an 8-foot-long displacement barrel into the well. The initial increase in the water level was about 4 feet. The sudden increase and subsequent slow decline of the water level was measured by a downhole pressure transducer. The effects of changes in barometric pressure were automatically compensated for by the transducer instrumentation.

The drawdown data were plotted as a function of time (fig. 12) and fit to type curves according to the method of Cooper, Bredehoeft, and Papadopoulos (1967). The best fit curve, $=10^{-4}$, indicated a transmissivity of 20 feet squared per day. Hydraulic conductivity of this 60-foot-thick sandstone bed is about 0.33 foot per day, which is similar to values calculated for the Jackpile sandstone bed. The storage coefficient indicated from the curve match is 0.0001. However, Cooper, Bredehoeft, and Papadopoulos (1967, p. 268) state that the value of storage coefficient calculated by this method is very sensitive to the type curve selected and therefore should be viewed only as an approximate value.

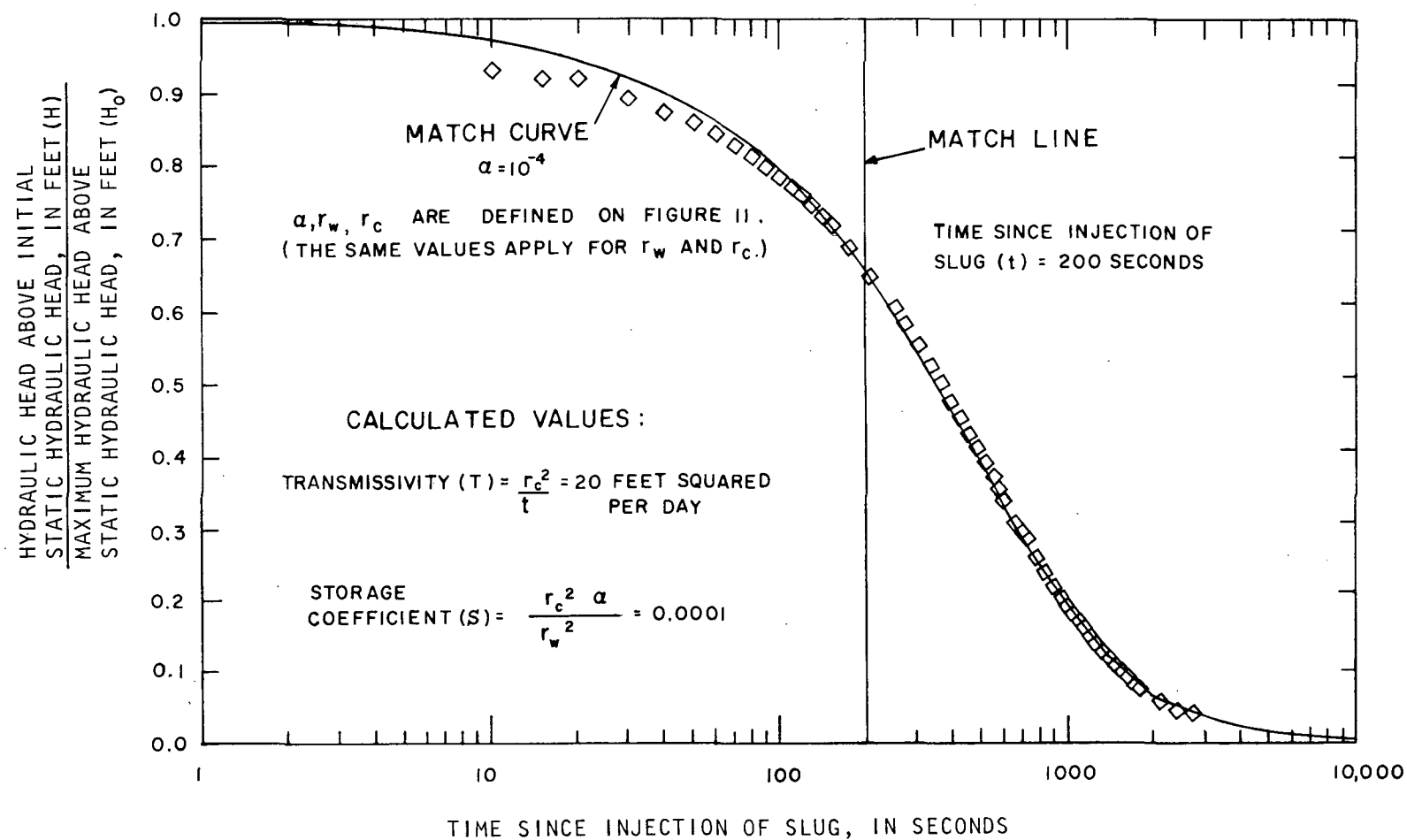


Figure 12.--Result of slug test for well M25.

SUMMARY

The hydraulic properties of alluvium near the junction of the Rio Paguete and Rio Moquino, the Jackpile sandstone bed, and an unnamed sandstone bed in the Brushy Basin Shale Member of the Morrison Formation were evaluated by aquifer testing. The results of the aquifer tests are summarized below.

Test site	Well M2	Well M3	Well M4C	Well M21	Well M25
Aquifer tested	Jackpile sandstone bed	Jackpile sandstone bed	Alluvium	Jackpile sandstone bed	Unnamed sandstone in Brushy Basin Shale Member
Type of test	Constant discharge	Constant discharge	Constant discharge	Constant discharge	Slug
Method used	Bolton, (1954)	Theis (1935)	Theis (1935)	Papadopulos and Cooper (1967)	Cooper, Bredehoeft, and Papadopulos (1967)
Duration of test, in hours	43	88	17.5	24	0.67
Average pumping rate, in gallons per minute	5.1	15.3	9.2	0.25	Instant- aneous slug
Saturated thickness at observation well, in feet	93	121	19	81	60
Transmissivity, in feet squared per day	24	47	430	2.0	20
Hydraulic conductivity, in feet per day	0.26	0.39	23	0.025	0.33
Storage coefficient	0.00018	0.00029	.0021*	0.00002	0.0001

*Apparent specific yield

The aquifer test at well M4C was monitored with observation wells in the alluvium and in the Jackpile sandstone bed. Water levels in the Jackpile sandstone bed responded rapidly to the pumping of water from the alluvium.

For the aquifer test at well M3, observation well M25, which is completed in an unnamed sandstone unit in the Brushy Basin Shale Member of the Morrison Formation, was monitored. The water level in well M25 changed a maximum of 0.03 foot during the 88 hours of pumping from the Jackpile sandstone bed, probably due to changes in barometric pressure. The negligible amount of drawdown indicates that the shale that separates the two units has a low vertical hydraulic conductivity that delays the hydraulic stress imposed during the test.

Well M21 and observation well M21ob were completed in the Jackpile sandstone bed and tested by pumping about 0.25 gallon per minute for 24 hours. Drawdown measured at observation well M21ob indicated that the transmissivity, storage coefficient, and hydraulic conductivity of the Jackpile sandstone bed probably were about one-tenth as large at this site as at other test locations.

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